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TEST METHODS FOR MEASURING ENERGY IN A GAS DISCHARGE

by

S. I. Reynolds

Report No. 55-RL-1443 November 1955

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REPORT NO. 55-RL-1443

TEST METHODS FOR MEASURING ENERGY IN A GAS DISCHARGE

S. I. Reynolds

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Published by
Research Information Services Section
The Knolls
Schenectady, New York

ABSTRACT

In order to study the degradation of insulating materials when subjected to high a-c voltages, two methods of test are usually used. In one method the solid dielectric in sheet form of a size large enough to prevent flashover, is placed between two metal electrodes and the voltage is increased until surface ionization and sparking occur at the edge of the high potential electrode. The material is then usually left on test until failure by breakdown occurs. The other method is to place the dielectric in a corona discharge through a gas, terminated at both ends by an insulating layer of glass. This method lends itself to simpler interpretation because tests can be made in a closed system.

The power consumed in the glass corona generator can be measured by either of two methods using equipment which is available in most laboratories. Agreement between the two methods is shown to be within a few per cent. It is also found that the corona power increases linearly with voltage, and that certain organic insulations, when subjected to ionization in a closed system with pure oxygen, degrade at a rate proportional to the measured power.

TEST METHODS FOR MEASURING ENERGY IN A GAS DISCHARGE

S. I. Reynolds

METHODS FOR MEASURING CORONA POWER

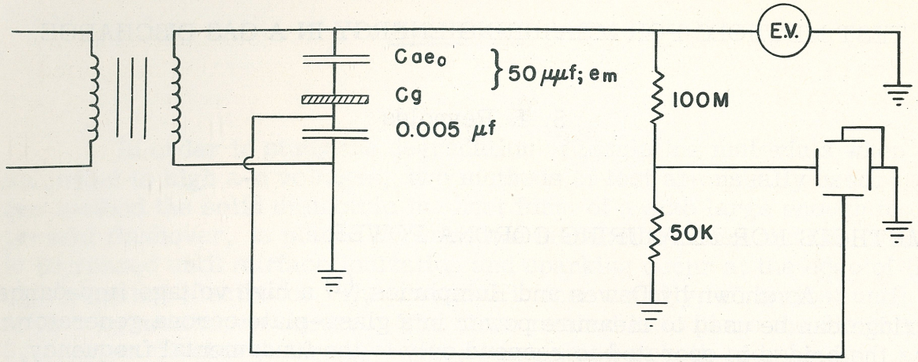
As shown by Dawes and Humphries, (1) a high voltage impedance bridge can be used to measure power in a glass-plate corona generator. As the bridge is operated to respond only to the fundamental frequency, in this case 60 cycles per second, the power measured by the bridge corresponds to the fundamental voltage and current in the test specimen.

The parallelogram oscilloscope technique has been used by T. C. Manley(2) to measure the power in an ozonator discharge. The circuit diagram for this method is shown in Fig. 1. When ionization starts, a parallelogram is formed as shown in Fig. 2. The X-axis displacement is proportional to the voltage, and the Y-axis displacement is proportional to the charge q in the system. By calibrating the scale divisions by means of a peak reading tube voltmeter, the peaks of voltage and charge are determined. One can then measure the area of the parallelogram to determine the power in watts.

The technique of area measurement is as follows. By means of a Polaroid Land camera, the scope trace and an illuminated scope screen are photographed. The area ABDE of the parallelogram (see Fig. 2) on the finished photographic print can then be measured accurately by means of a planimeter.

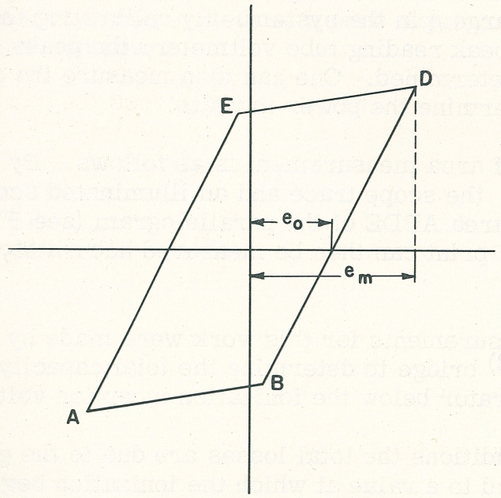
The bridge measurements for this work were made by means of a high voltage Schering(3) bridge to determine the total capacity and loss angle of the corona generator below the ionization inception voltage.

Under these conditions the total losses are due to the glass, and when the voltage is raised to a value at which the ionization begins, the losses immediately increase because of the ionization current. The total capacity of the generator, the loss angle, and the frequency of the sine wave current can then be used to calculate the equivalent parallel conductance of the test cell by the formula $G = \tan\delta\,\omega\,C$. Once the conductance is determined as a function of voltage, above the ionization inception voltage, the power dissipated is calculated from the formula $W = E^2G$, where G is the total conductance across the test cell and E is the rms applied voltage.



T.C. MANLEY, TRANS. ELECTROCHEM. SOC. 84, 82 (1943)

Fig. 1 Circuit diagram of oscillograph connections for corona measurements.



PARALLELOGRAM ABDE

POWER DISSIPATED PER CYCLE = AREA = $4\, C_g e_o (e_m - \frac{C_a}{C} e_o)$

MAXIMUM EXTERIOR CHARGE = $g_m = C_g (e_m - e_o)$

Fig. 2 Power diagram from oscilloscope trace.

The power in watts from the bridge measurements and from the parallelogram methods is shown in Fig. 3 as a function of applied peak voltage.

Manley[2] has shown that the power W dissipated in the air gap in series with a dielectric as shown in Fig. 1 can be calculated from the following equation

$$W = 4f\, C_g\, e_o\, (e_m - \frac{C_a}{C} e_o),$$

where

e_m = peak value of secondary voltage

e_o = discharge potential across the gap

C_a = capacity of air space alone

C = total capacity where $\frac{1}{C} = \frac{1}{C_a} + \frac{1}{C_g}$

C_g = capacity of the glass dielectric.

If it is assumed that the spark potential of a gas between metal electrodes is the same as the sparking potential across the gap between dielectrics, the corona starting voltage can be calculated if the air gap spacing is known and the series capacities C_a and C_g are determined by guarded bridge measurements.

The corona starting voltage $V_{cs} = \left(\frac{C_a}{C_g} + 1\right) V_s$; therefore, the power in watts is given by

$$W = 4f\, V_s\, C_g\, (V_o - V_{cs}),$$

where

V_o = peak value of secondary voltage

C_a = air gap capacity calculated

C_g = dielectric capacity measured

V_s = sparking potential for a given pressure and gap

V_{cs} = corona starting voltage, calculated peak value.

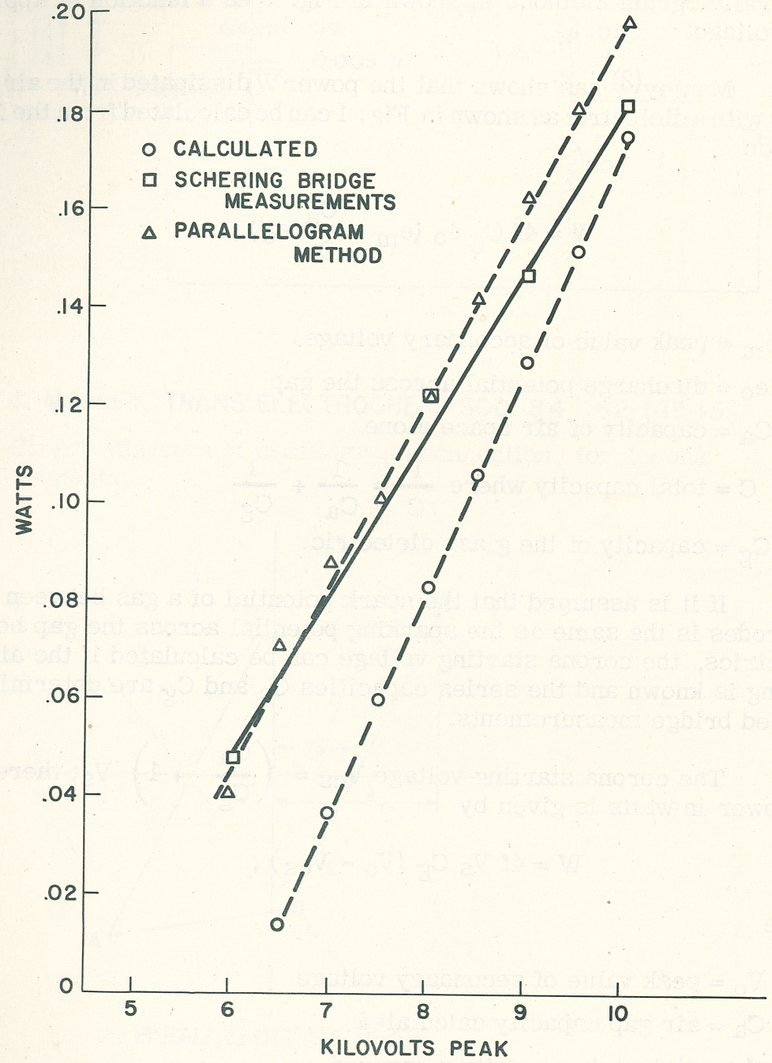


Fig. 3 Power in watts versus peak kilovolts from bridge and parallelogram methods.

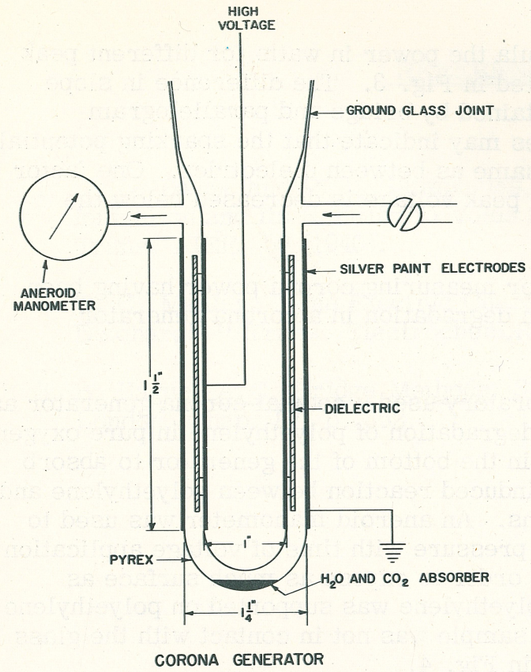


Fig. 4 Schematic diagram of coaxial all-glass corona generator.

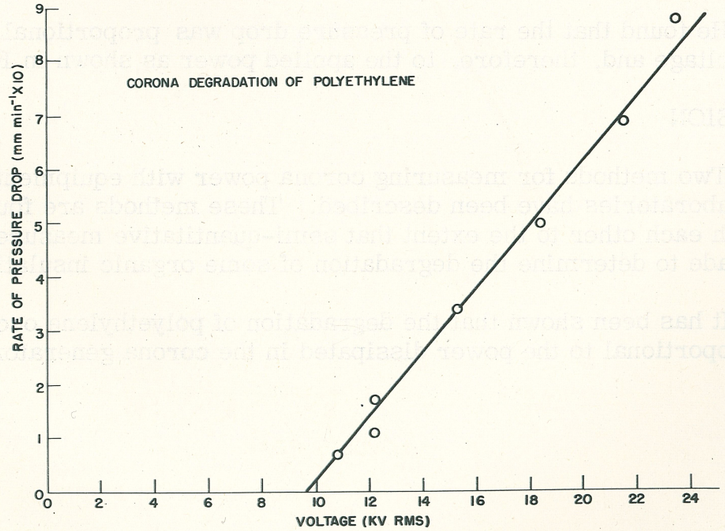


Fig. 5 Corona degradation of polyethylene.

By the use of this formula the power in watts for different peak voltages was calculated and plotted in Fig. 3. The difference in slope between the measured values obtained by bridge and parallelogram methods and the calculated values may indicate that the sparking potential between metal plates is not the same as between dielectrics. One factor is ionization persisting after the peak voltage is decreased below the starting potential.

Two suitable methods for measuring corona power having been established, a study of insulation degradation in a corona generator system is in order.

John Devins of this laboratory used a coaxial corona generator as shown in Fig. 4 to measure the degradation of polyethylene in pure oxygen by placing Drierite and Ascarite in the bottom of the generator to absorb the CO_2 and H_2O formed by the induced reaction between polyethylene and oxygen under ionization conditions. An aneroid manometer was used to measure the decrease of oxygen pressure with time of voltage application for a given amount of power. In order to expose as much surface as possible to the discharge, the polyethylene was supported on polyethylene rings in such a way that the test sample was not in contact with the glass walls of the generator as shown in Fig. 4.

He found that the rate of pressure drop was proportional to the applied voltage and, therefore, to the applied power as shown in Fig. 5.

CONCLUSION

Two methods for measuring corona power with equipment available in most laboratories have been described. These methods are found to agree with each other to the extent that semi-quantitative measurements can be made to determine the degradation of some organic insulations.

It has been shown that the degradation of polyethylene occurs at a rate proportional to the power dissipated in the corona generator.

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3. B. Hague, A.C. Bridge Methods, Sir Isaac Pitman and Sons, Ltd., London, Chap. IV, p. 352.

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TITLE: Test Methods for Measuring Energy in a Gas Discharge 15-605

ABSTRACT

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